Solar Dynamics Observatory

Gauging the solar climate

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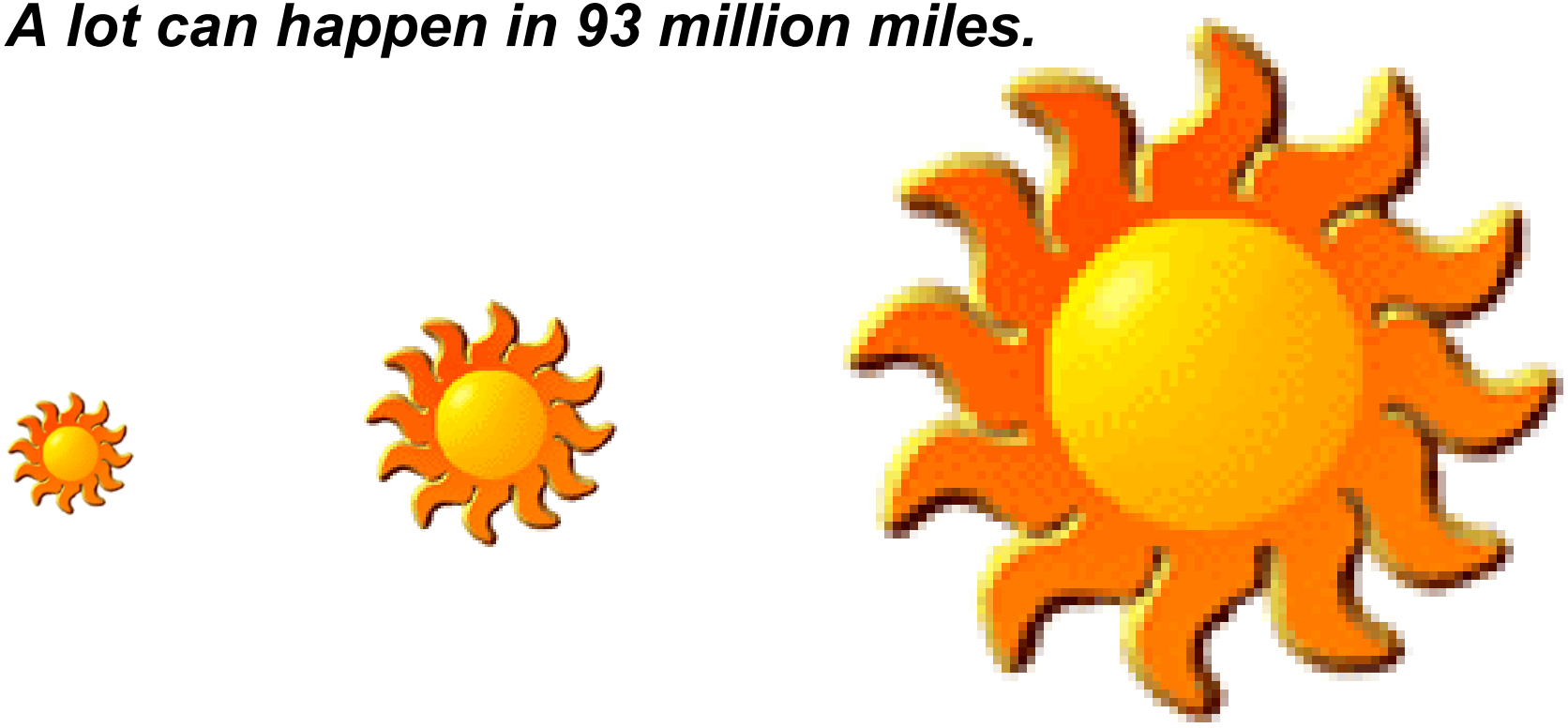
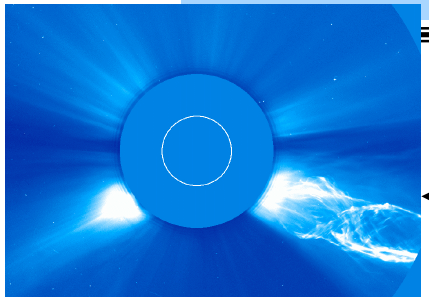
The SDO Philosophy

- At the center of our solar system lives a highly variable magnetic star.

- A lot can happen in 93 million miles.



Solar Dynamics Observatory - Next Generation SOHO



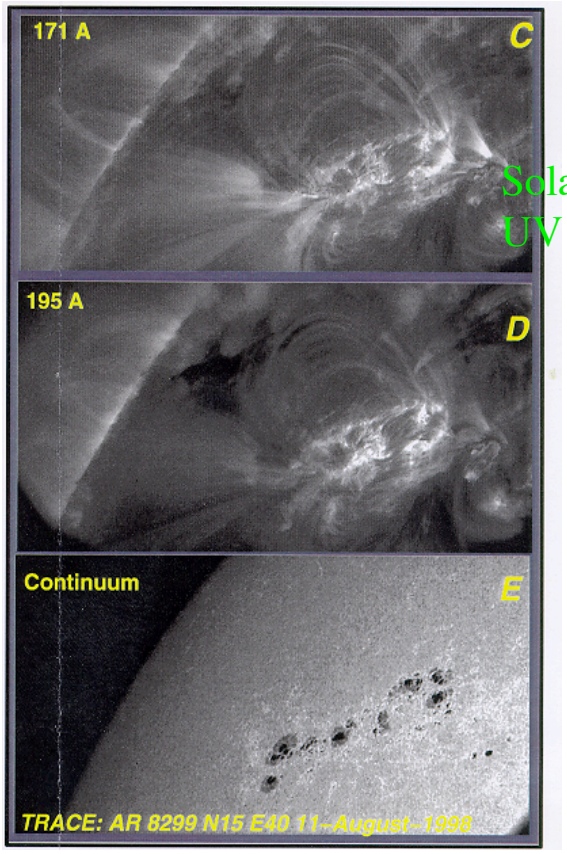
Imaging CME'S

- **Investigating solar dynamical processes and phenomena**
- **Observing development of magnetic and subsurface phenomena**

related to 1) flare &CME energy storage & triggering

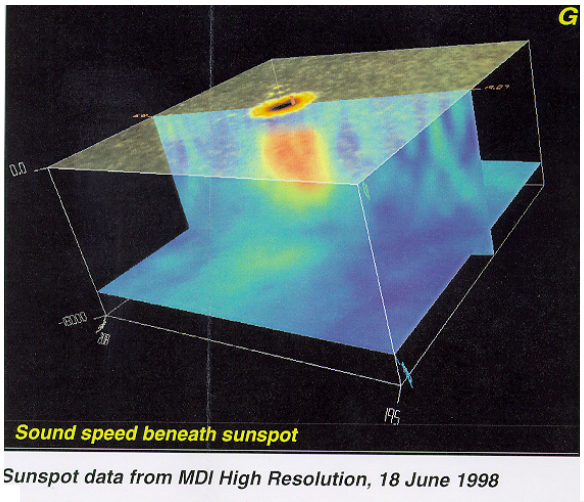
2) The solar dynamo driving the solar cycle.

- **High data rate from GEO orbit for studying dynamics (SOHO limited by low data rate from L1)**



Solar EUV and UV Irradiance

Imaging Magnetic Structures
(rapid time sequences -- "movies")



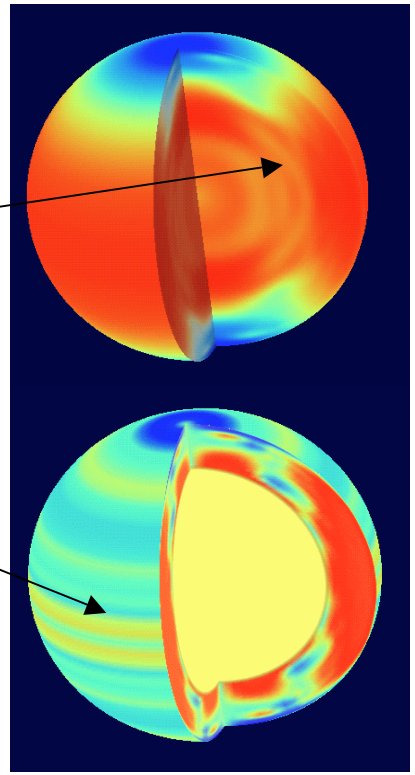
Sunspot data from MDI High Resolution, 18 June 1998

Imaging Subsurface Structures

Red: Faster Rotation
Blue: Slower Rotation

Solar Dynamo?

Link to solar cycle?



Imaging Solar Interior

SDO Status

- Currently roadmapped as “SONAR”
- Entering IMDC conference next week (14 Feb 2000)
- Development of challenges and partnerships essential to SDO’s success
- Preliminary Mission Definition Team has been established

Top Level Goals

- To understand basic physical processes in the Sun and its extended outer atmosphere
- To be a part of the Living with a Star (LWS) program which aims to understand the coupled physics of the Sun, the interplanetary medium, the Earth's magnetosphere and atmosphere, and Global Change
- To develop predictors of various solar processes to aid in the forecasting of events of potential danger or damage to workers in space, scientific and commercial spacecraft, high-altitude aircraft, and the Earth's communications and power-distribution systems.

Scientific Goals

- To understand how magnetic fields appear, distribute, and disappear from their origin in the solar interior to 18 solar radii from the solar surface.
- To understand the magnetic topologies that give rise to rapid high energy release processes that occur on scales from a thousand to many hundreds of thousand kilometers.
- To study and gauge the dynamic processes which influence space weather phenomena

Major Science Questions

- Why are there sunspots and solar active regions?
- How do magnetic regions emerge, evolve and decay?
- How do the active-region fields interact with the small-scale fields?
- Do local dynamo processes occur?
- How does the large amount of magnetic energy that is created at small scales dissipate?
- How are small and large-scale coronal magnetic field reorganizations related?

Major Science Questions

- What are the surface and subsurface magnetic configurations that lead to CME's, flares and SEP's?
- How important are cascading processes of flux emergence to large-scale flux evolution and expulsion?
- To what extent are transient eruptive phenomena predictable?
- How do active regions and the quiescent magnetic field affect solar convection and irradiance?
- How does this irradiance in turn affect near-Earth space?
- How are the dynamics of the interior and the quiet and active solar corona linked?

The SDO Approach

- Observe the solar interior from the core to the surface.
- Image the top half (in pressure and density) of the convection zone.
- Measure the vector magnetic field at the solar surface.
- Image the upper atmosphere and corona in temperature regimes from 4 10^3 to 9 10^6 K.
- Measure the solar luminosity and irradiance in the UV and EUV.

The SDO Method

- Observe continuously for many months at a time
- Make all visible and UV images simultaneously on a 10 second cadence
- Make vector magnetograms on a 5 minute cadence
- Make surface velocity measurements on a 45 second cadence
- Make a well defined and unchanging set of measurements

What we hope to provide for you

SDO Data Products

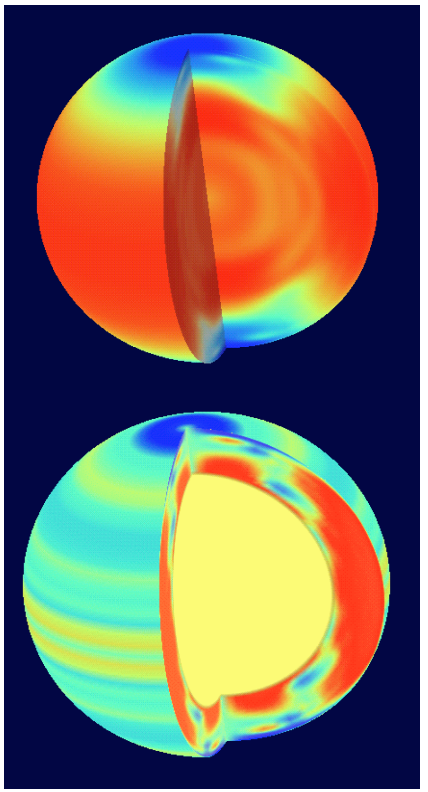
- Maps of the Interior flows, temperatures, and magnetic fields,
- Maps of surface Vector Magnetic field (20 seconds) and velocity pattern (5 seconds),
- High Resolution stigmatic spectra,
- Images of the Corona at temperatures that span 40,000 K to 9,000,000 K (10 seconds),
- Images of the electron density, white light corona, from 0.05 to 30 Solar Radii (10 seconds),
- Irradiance Maps of the surface.

SDO Instrument Complement

- Helioseismic and Magnetic-field Imager (HMI)
- Atmospheric Imager Assembly (AIA)
- Coronal Imager Assembly (CIA)
- Irradiance Monitor
- *Spectroscopic Imager*
- *Soft X-ray imager*
- *Additional viewpoints*

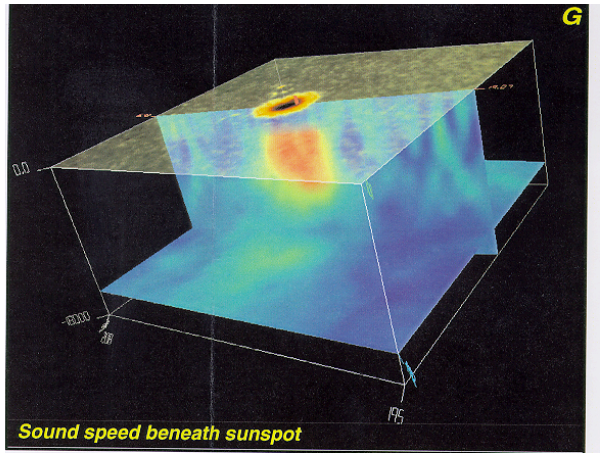
HMI: Helioseismic and Magnetic field Imager

- Modified version of Michelson Doppler Imager on SOHO
- Deletes Dual Image Scale mode of MDI
- Contains separate filter systems for Helioseismology and Magnetic fields
- Contains 2 4096 x 4096 CCD's (one Doppler-one Magnetic)
- FOV 36 x 36 arc minutes
- Pixels size 0.527 arc seconds



Red: Faster Rotation
Blue: Slower Rotation

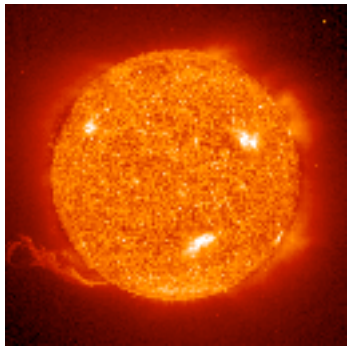
HMI Properties

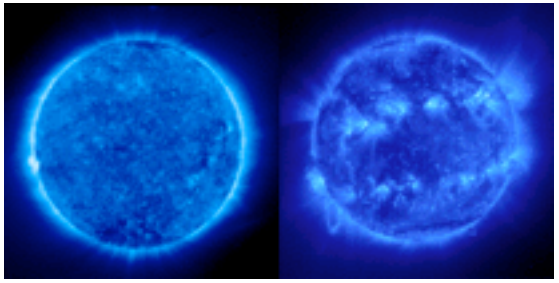


- Aperture 12.5 cm
- Optics Package wt 24 kg
- Data Rates
  - One 4096 x 4096 by 8 bit Doppler data product every 5 seconds ~2.7 10^7 bits/sec
  - One 4098 x 4096 by 6 bit Magnetic Data Product every 20 seconds ~ 6.7 10^6 bits/sec
- Data Products
  - One Helioseismology data set every 45 seconds
  - One Vector Magnetogram every 5 minutes

AIA: Atmospheric Imager Assembly

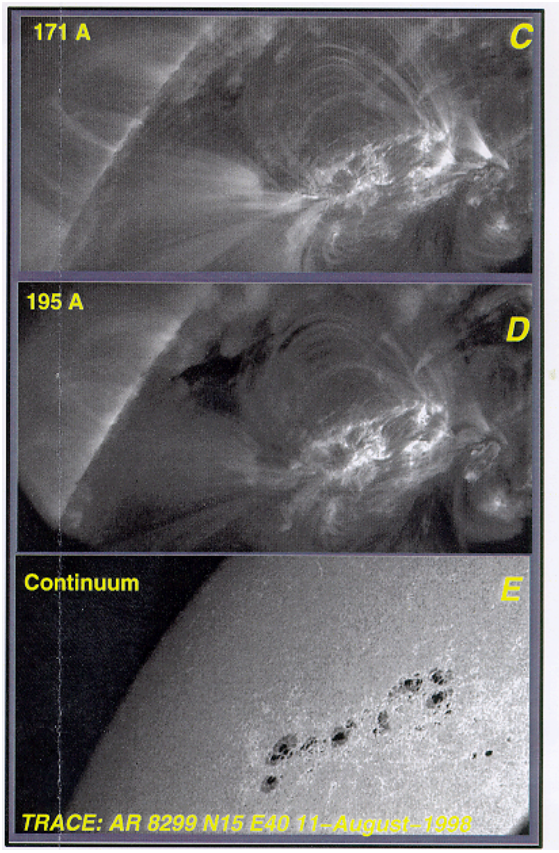
- Six .5” scale versions of the TRACE or EIT telescopes mounted as a cluster.
- Each of the EUV telescopes is dedicated to a single wavelength band.
- A visible-UV telescope contains a filter wheel with 6 wavelength channels.
- All of the telescopes can expose simultaneously.





AIA Properties

- Telescope Aperture 12 -15 cm
- Telescope Length 1.3 meters
- FOV 36 x 36 arc minutes
- Pixel Size 0.527 arc seconds
- Each telescope has a 4096 x 4096 CCD
- Data Rate is one image every 10 seconds in 10 wavelengths
  - Six Simultaneous
  - 6.76 10^7 bits/second



AIA EUV Wavelengths

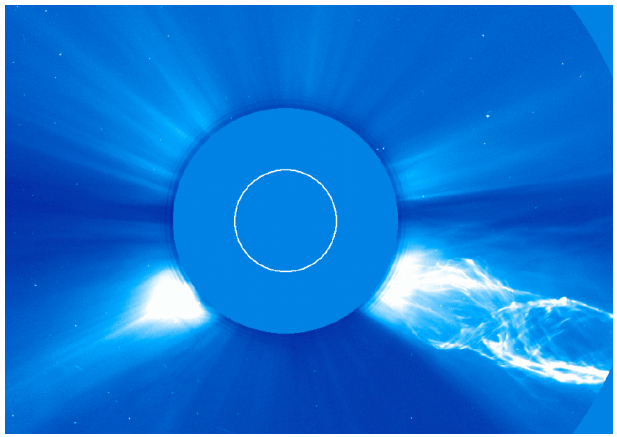
- 304 He II 100,000 K
- 171 Fe IX 800,000 K
- 195 Fe XII 1,000,000 K
- 211 Fe XIV 1,600,000 K
- 284 Fe XV 2,000,000 K
- 133 Fe XX 9,000,000 K

AIA UV Wavelengths

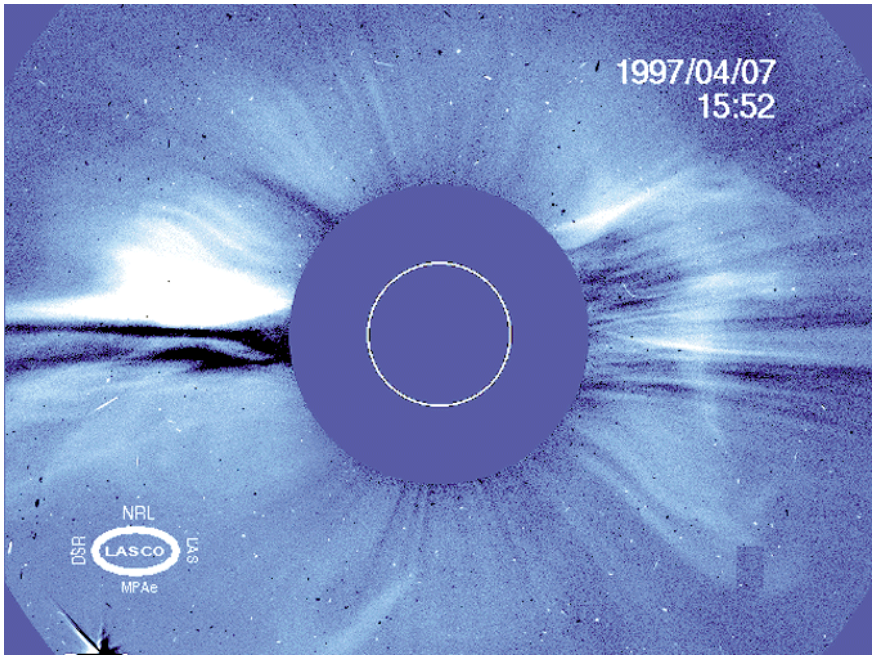
- 1900 Continuum
- 1700 Continuum
- 1600 Continuum
- 1550 Narrow Band C IV
- 1216 Narrow Band H I
- Broadband Visible

Coronal Imager Assembly (CIA)

- Two Coronagraphs
- Inner Coronagraph Overlaps AIA FOV
- Outer Coronagraph Overlaps Inner
- Both Make Polarization Measurements



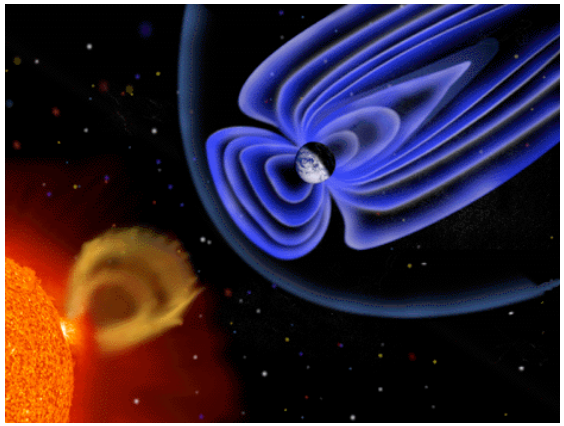
Inner CIA Properties



- Telescope Aperture TBD
- Telescope Length TBD
- FOV 33.6 to 72 arc minutes
- Pixel Size 1.054 arc seconds
- Telescope has a 4096 x 4096 CCD
- Data Rate is one image every 10 seconds in 4 Polarization States
  - 2.68 10^7 bits/second

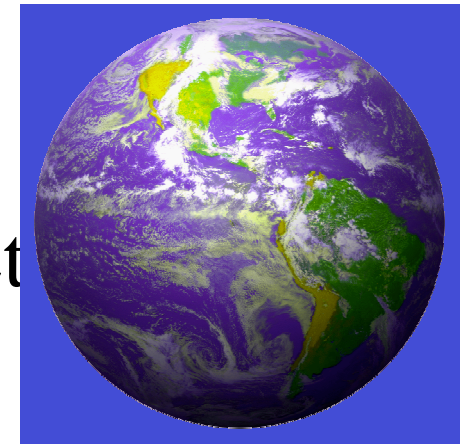
Outer CIA Properties

- Telescope Aperture TBD cm
- Telescope Length TBD meters
- FOV 2 to 18 Solar Radii
- Pixel Size 8.422 arc seconds
- Telescope has a 4096 x 4096 CCD
- Data Rate is one image every 10 seconds in 4 Polarization States
  - 2.68 10^7 bits/second



Irradiance Monitor

- Based on SEEC study (Sun-Earth Energy Connector) but not to be used as a replacement of the entire suite of proposed instrumentation.
- Proposed total irradiance and EUV optics-free irradiance spectromet
- 1-1000 Å irradiance at 1-2 Å spectral resolution
- Greatest potential for development as an instrument and as a data product



SDO Challenges

Research Challenges:
the Proposed Taming of the Shrew

- A Focused Scientific Research Problem that requires a range of expertise.
- A problem that has important consequences for understanding and has important effects on the Sun-Earth system.
- A problem that will require 3 or more years of sustained effort.
- Tailoring of “deliverables” if necessary: add utilities in addition to scientific publication as the potential outcome of the work

The Distributed SEC Laboratory

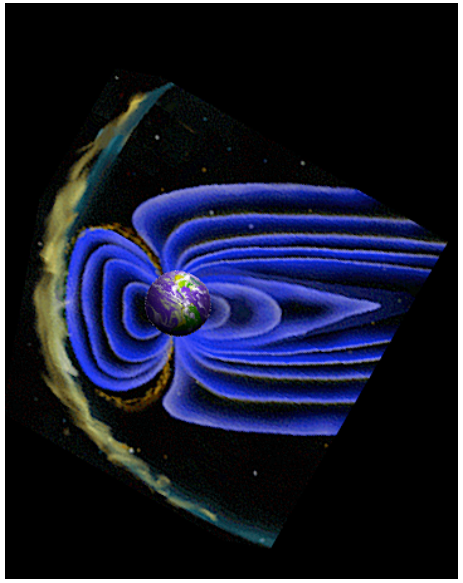
- Near real-time data availability prioritized for users
- No proprietary data
- All SDO and as much other data as possible accessible via a single catalog and data base.
- All numerical simulations and models supported by LWS also available via the catalog.
- Development centers of 3D visualization techniques for connecting different data sets.
- Create focused visualization centers associated with Challenge teams.

SDO and other future projects

- The Stereo Mission will provide data on the 3D structure of the corona.
- The Solar B mission will provide very high resolution vector magnetic field data and spectral imaging.
- The ESA-F Mission will join SDO as part of the Next Generation SOHO.
- Other vantage points: Solar/Polar, Sentinels

What you can do for us

- Help us identify data products which will be of immediate utility
- Help us tailor research challenges to optimize the impact of the results



- Begin early to identify support structures and agreements across agencies
- Have mechanisms in place to utilize the data and research; be able to demonstrate their utility and impact

How do we ensure partner agency participation?

Proposed Challenge Topics

1) "Whole Sun" modeling initiative challenge

GOAL: determine the observables required and the model components needed to build a 3-D model of the Sun

2) Irradiance initiative - work with current modellers who use irradiance as inputs to models, work with modellers who are interested in using irradiance inputs, assess current irradiance initiatives and their ability to fully characterize the solar input to earth, irradiance studies over long term

GOAL: understand which regimes in irradiance are necessary to understand earth's response, identify which regimes (spectral and continuum) need augmentation in the future

3) SEC data studies - “data farming” - Vondrak’s “information extraction” correlative studies of various phenomena, determine which serve as good indicators, which correlations can be relied upon, SEP, CME, shocks, timing, magnetic field, radio bursts, CIRs. How are we distinct from the NRC Space Weather announcement?

GOAL: pour over existing data to demonstrate space weather prediction, magnitude assessment capabilities